Is the impact of K deficiency on cotton (*Gossypium hirsutum*) mainly due to a dysfunction in growth, photosynthesis or water characteristics?

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Introduction

- K deficiency stays a major contraint in the modern crops USA (Pettigrew, 2003), Australia (Wright, 1999) as in traditional crop like in Africa.
- Conséquences:

  low yield

  low quality

  increase sucking insect number and damage

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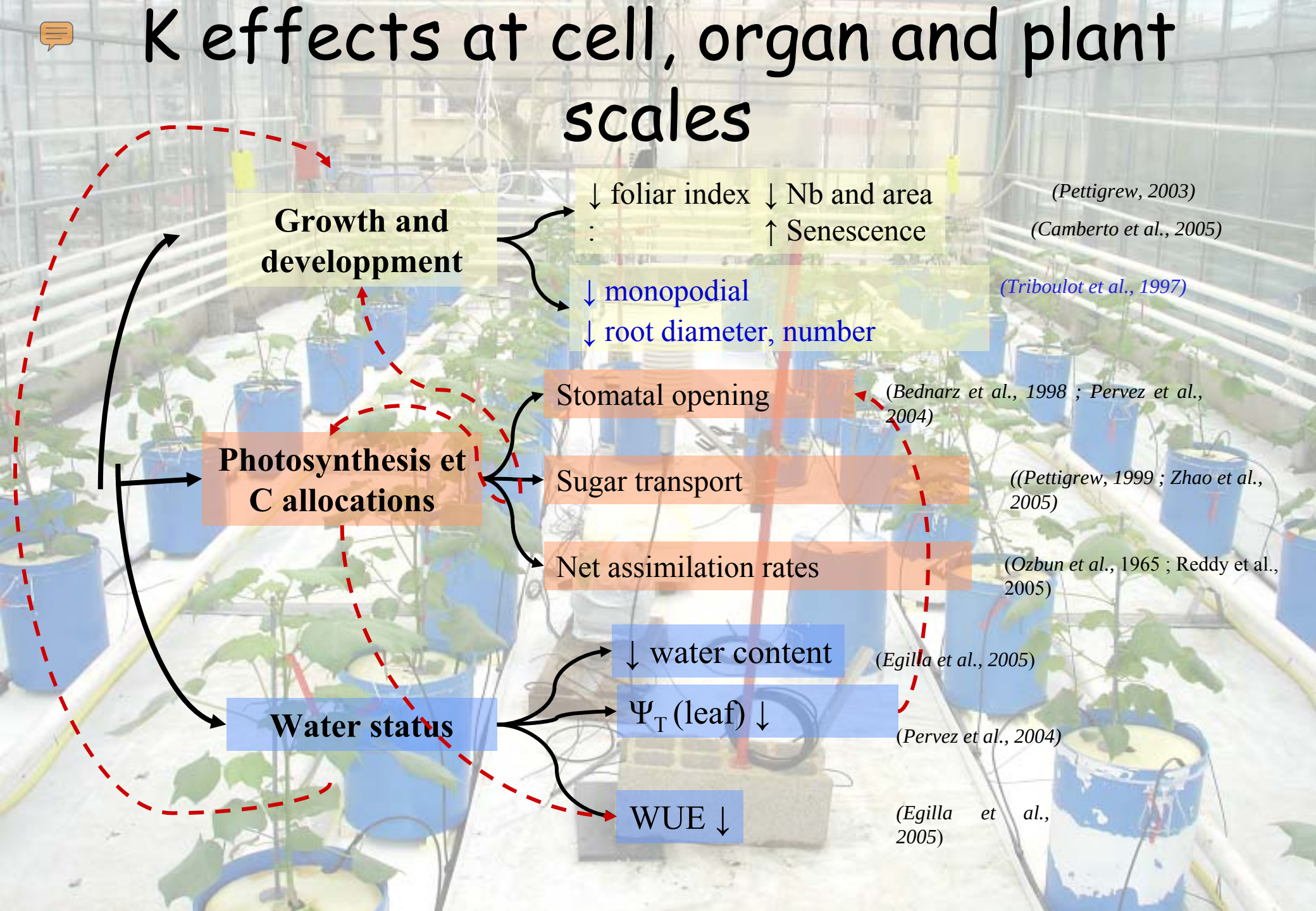
K play many roles at many levels

On growth and development first, it affects foliar index by reducing number, individual size and life duration of leaves. It also affects aerial and root architecture
On photosynthesis and carbon allocation it affects stomatal opening, sugar transport and net assimilation rates
On water relation K deficiency affect water potentials, content and water use efficiceny of photosynthesis.

As it is a complexe system all these functions are in interaction as illustrated by red doted lignes.

K effects at cell, organ and plant scales



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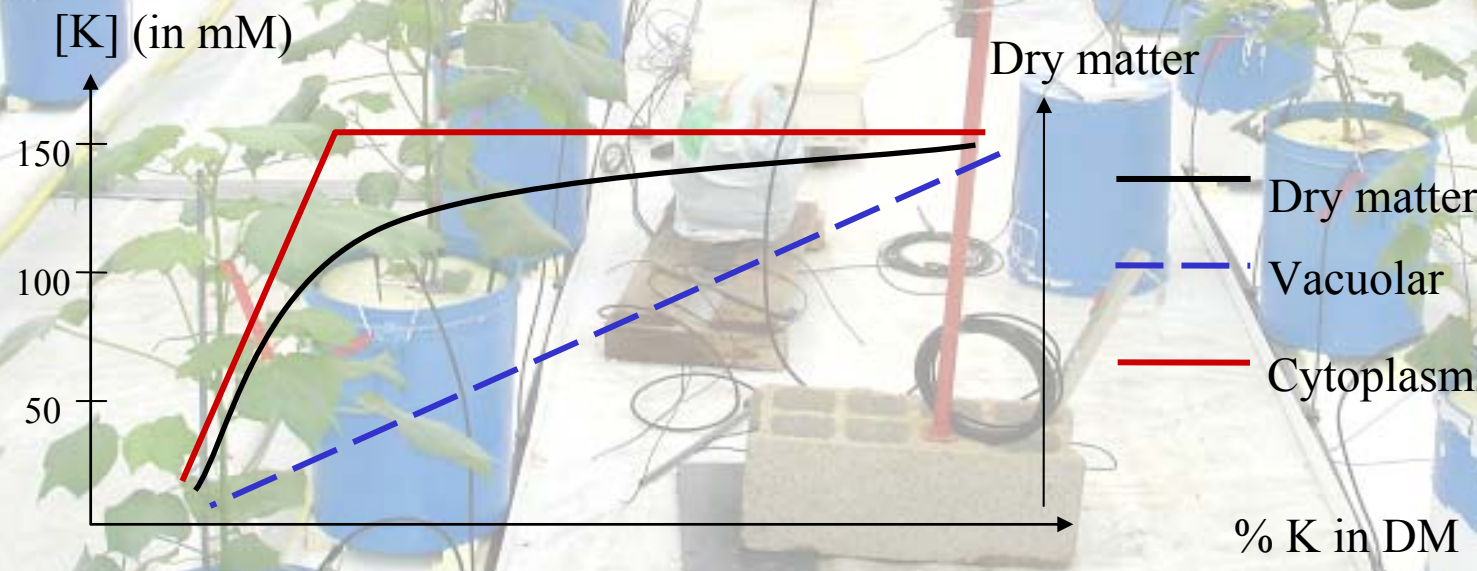
An operational classification of the roles played by K on plant growth proposed by leigh and wyn jones. It makes the distinction between vacuolar and cytoplasmic K.

K cell compartment

(Leigh et Wyn Jones, 1989)

K → biophysical activity → Vacuolar

K → biochemical activity → Cytoplasmic



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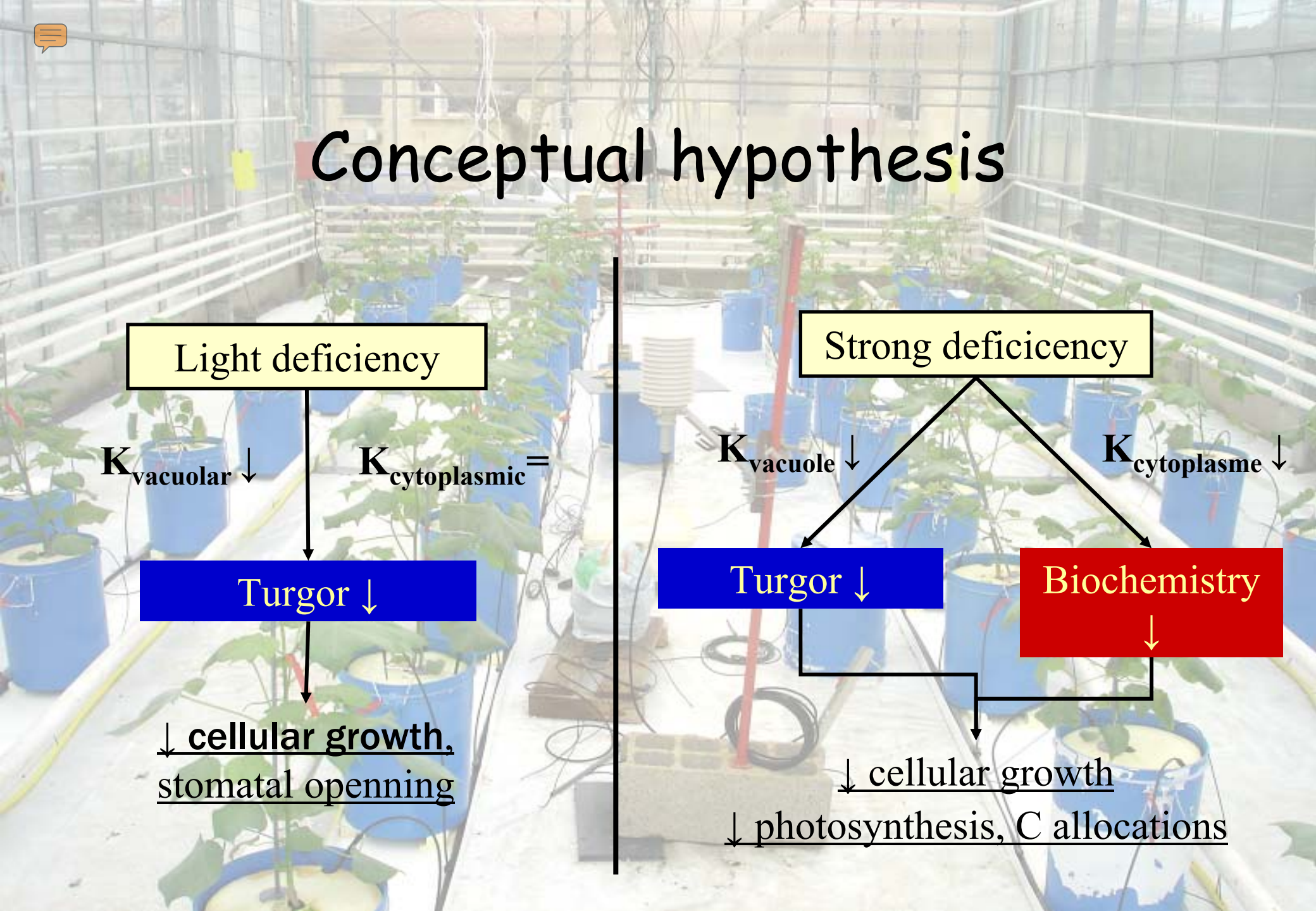
Therefore, we assume that in case of a slight deficiency, only turgor maintenance would be reduced, leading to a lower cell growth; severe deficiency would lead to additive effects such as photosynthetic and carbon disruption.

Conceptual hypothesis



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The experiment took place in a greenhouse located at Bordeaux (SW France) in March and April 2006. After germination, 60 cotton seeds were transplanted into individual 24L plastic containers. These held aerated standard nutrient solution with K. The pH was adjusted near 6. The solution was weekly renewed. Twenty plants were used for continuous non-destructive recording of plant stage, architecture and leaf area. Every 150 °C days (base 13°C), five plants per treatment were randomly sampled for additional observations on roots, leaves and stem: biomass, main cations (K, Ca, Mg, Na). Leaves were used for particular measurements such as water and osmotic potentials. Soluble sugars were measured on mature and early-emerged leaves and on main root growing zones. A gas exchange analyser (LI-6400) was used to determinate the photosynthetic parameters proposed by (Farquhar, Von Caemerer et al. 1980).

Material and methods

4 K treatments in hydropic conditions (0.02 – 0.06 – 0.3 - 3 mM, K0, K1, K2, K3).

20 plants/treatment
5 replications

DM and leaf area

Water and osmotic potentials

Soluble sugars

Major cations

Photosynthesis response curves

results

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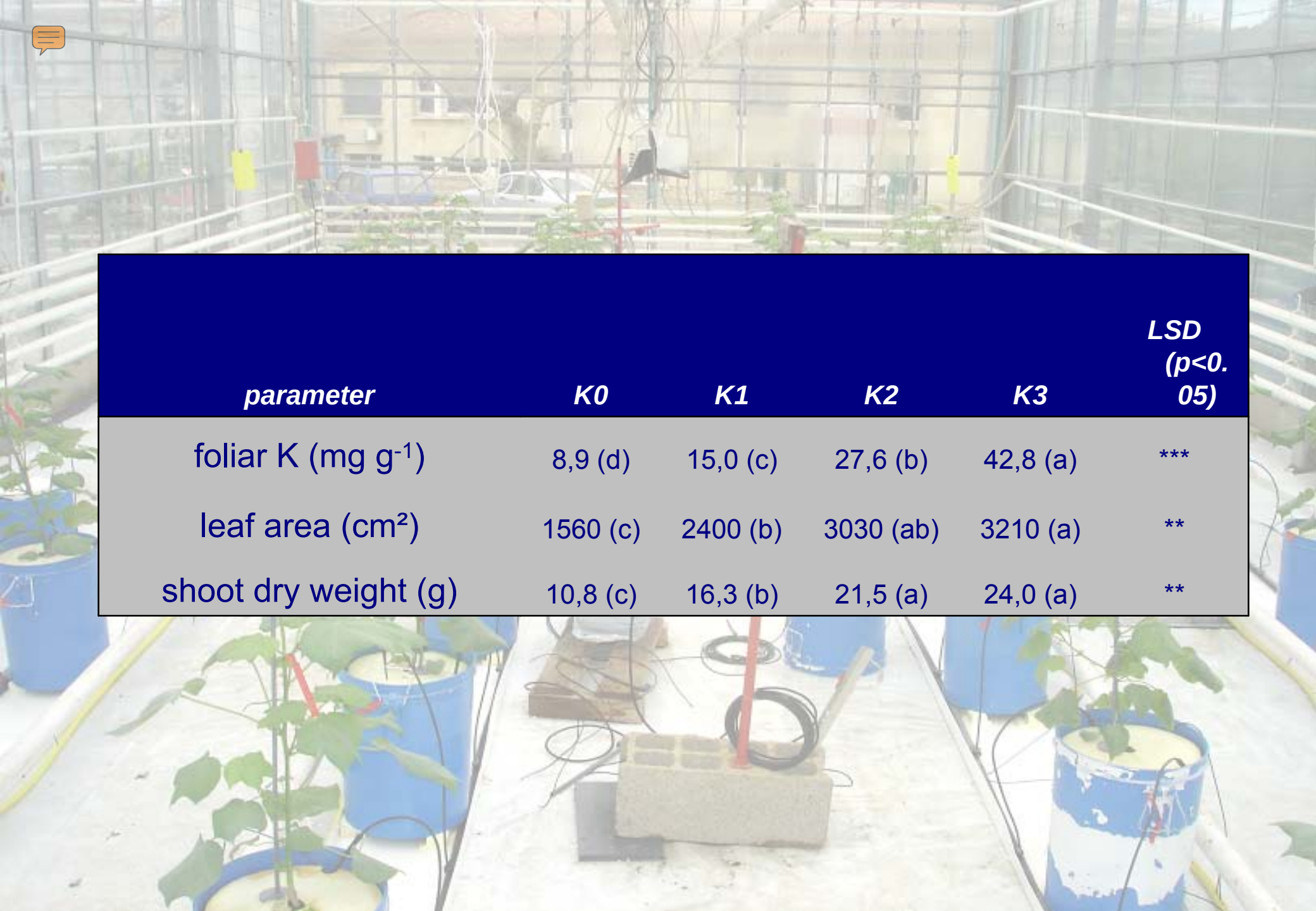
We obtained o broad range of leaf K content at 350 ° days from 9 to 40 mg/g. . Parallel to K starvation, higher Ca and Mg concentrations are observed, but the total amount of cations (K + Ca + Mg + Na) in K starved plants does not fully compensate for the lack of K. At 350°days, mean shoot dry matter (DM) and leaf area of K0 are 2 times lower than K3.



parameter	*K0*	*K1*	*K2*	*K3*	*LSD (p<0.05)*
foliar K (mg g^{-1})	8,9 (d)	15,0 (c)	27,6 (b)	42,8 (a)	***
leaf area (cm^2)	1560 (c)	2400 (b)	3030 (ab)	3210 (a)	**
shoot dry weight (g)	10,8 (c)	16,3 (b)	21,5 (a)	24,0 (a)	**

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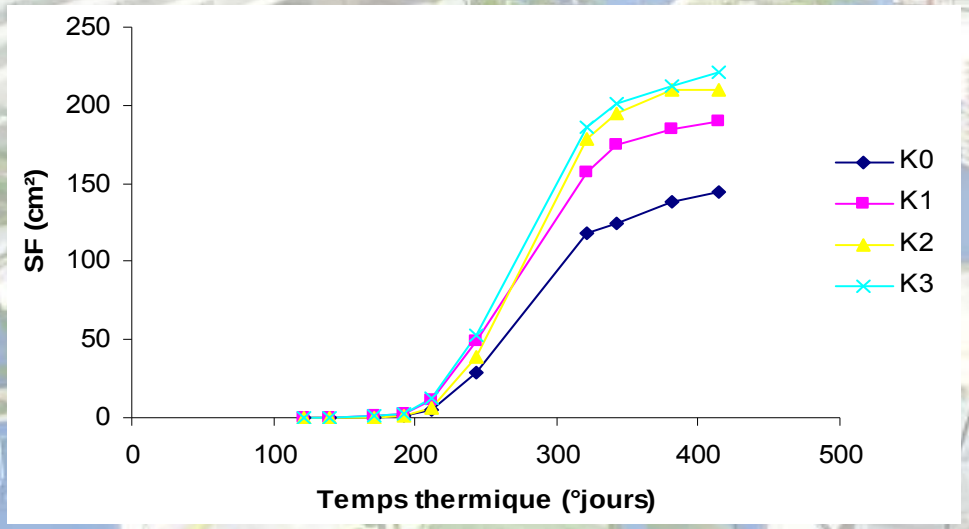
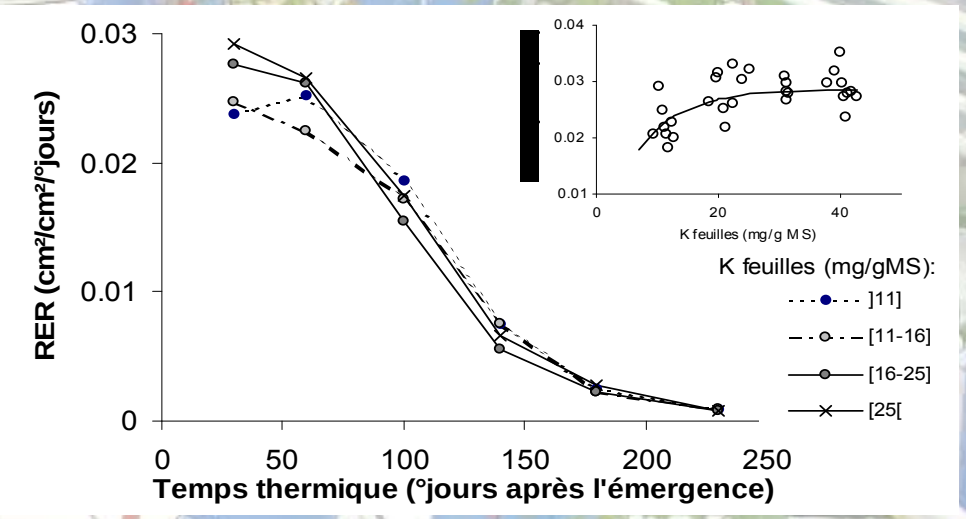
The reduced leaf area is not due to a higher senescence (data not shown) or a shorter growth duration but to a lower relative leaf growth rate (RGR) just after leaf emergence (< 50°Cdays). This negative influence of K on RGR is particularly important below 10 mgK/g (fig. 2). This reduced RGR occurs only during early stage of leaf growth when organs are still heterotrophic.

Leaf area


SF (cm²)
250
200
150
100
50
0
0
100
200
300
400
500
Temps thermique (°jours)
K0
K1
K2
K3


RER (cm²/cm²/°jours)
0.03
0.02
0.01
0
0
50
100
150
200
250
Temps thermique (°jours après l'émergence)
0.04
0.03
0.02
0.01
0
20
40
K feuilles (mg/g MS)
K feuilles (mg/gMS):
]11]
[11-16]
[16-25]
[25[

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Maximum assimilation rate is reduced from 39 to 29 mmol CO2/m²/s. This is due to lower stomatal conductance and at the same time to a dysfunction in carboxylation (Vcmax) . K deficiency does not affect electron transport (Jmax) quantum efficiency (alpha) or respiration (Rd).

parameter	K0	K1	K2	K3	LSD p<0.05
Amax (µmol CO_2 m^2s^{-1})	29,6 (b)	34,6 (ab)	35,6 (ab)	39,1 (a)	*
Gs (mmol m^2s^{-1})	0,50 (b)	0,60 (b)	0,70 (a)	0,71 (a)	*
Vcmax µmol CO_2 m^2s^{-1}	105 (b)	158 (a)	164 (a)	176 (a)	**
Jmax µEq $gChl^{-1}$ m^2s^{-1}	150	175	210	208	NS
alpha mol CO_2/mol photons	0,30	0,26	0,31	0,34	NS
Rd µmol CO_2 m^2s^{-1}	-6,6	-7,9	-5,7	-11,7	NS

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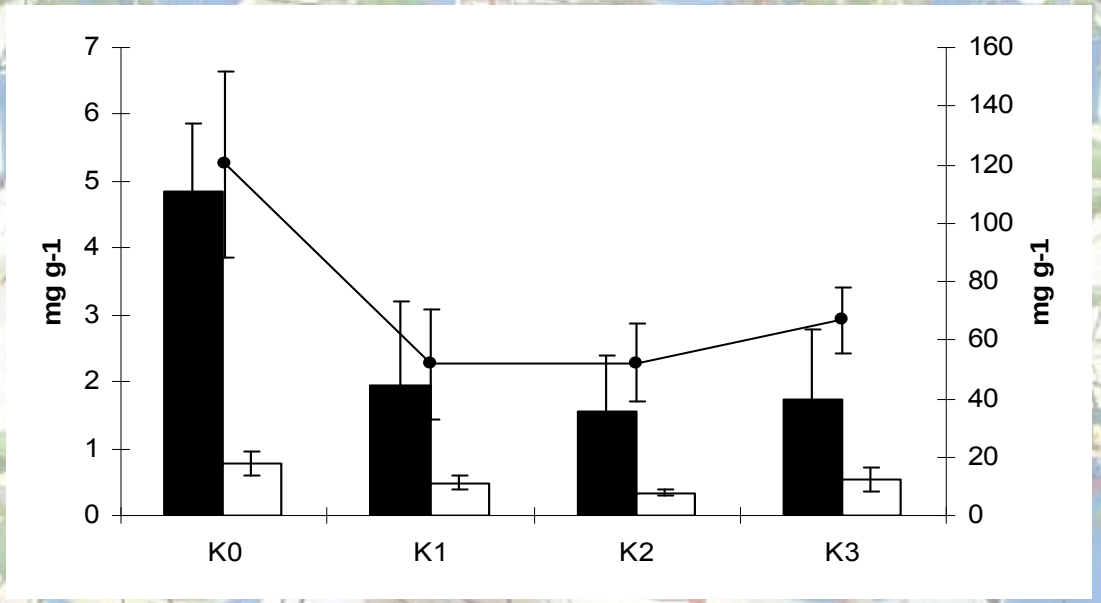
In spite of photosynthesis reduction, soluble sugars, especially saccharose and glucose, are more than twice more concentrated in K0 than in K3 mature leaves Consequently, Specific Leaf Weight is higher, and carbon is preferentially located in leaves to the detriment of roots and stems. Soluble sugars in early-emerged leaves decreased with K deficiency; this could be linked to a disruption in saccharose transport from source to sink organs. Turgor pressure of leaves at dawn was not significantly different between objets.

Sugar content of leaves



foliar sugar concentration as a function of K treatments. Values are the means of the first fully expanded leaf of 5 plants at 350° days after planting. Vertical bars give the standard deviation. Dark bars: glucose (left Y axis), white bars: fructose (left Y axis), dots :

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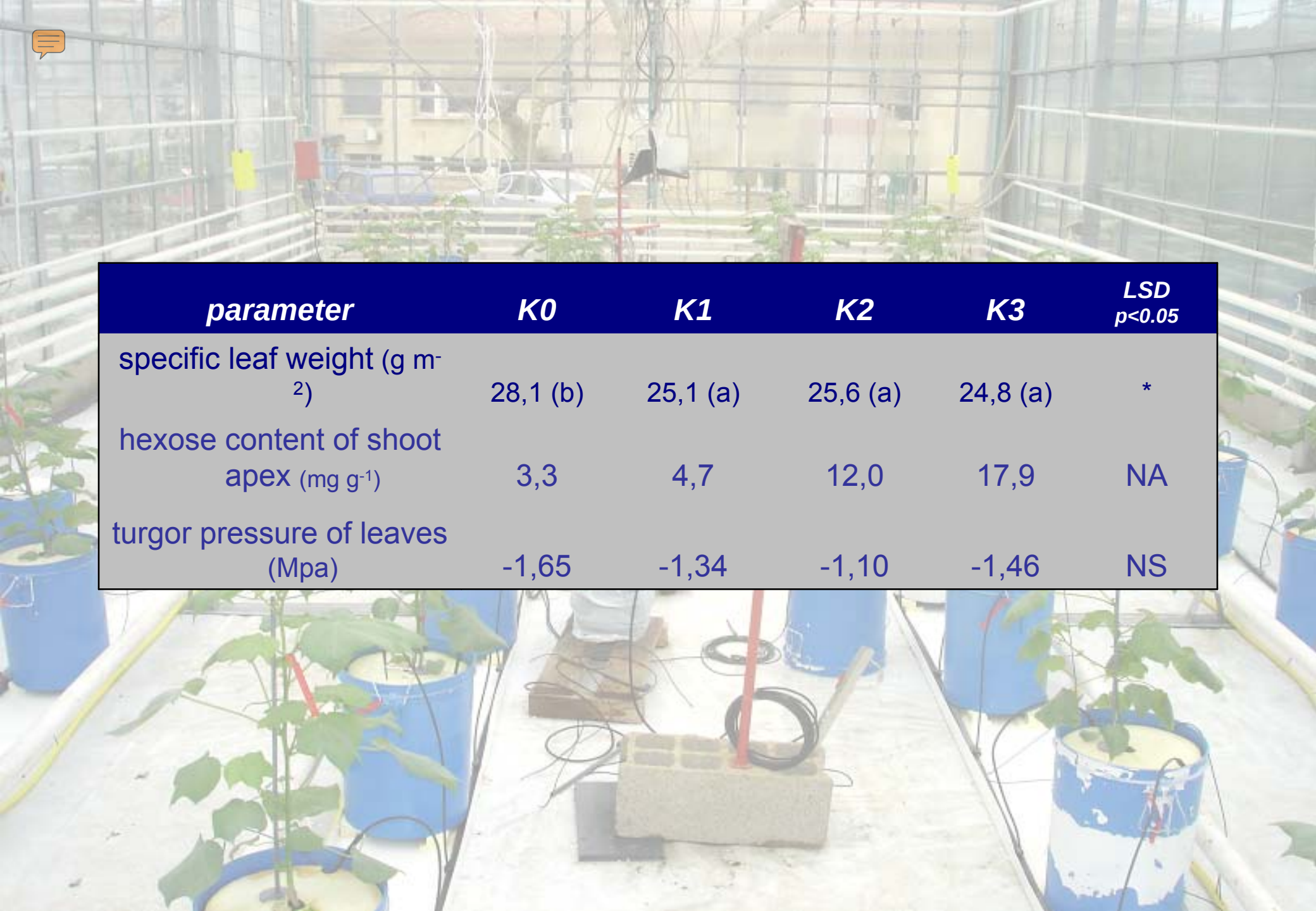
To explain reduce RGR, we can also see the hexose content of shoot apex.
On an other hand, turgor pressure of leaves where not affected by K treaments.



parameter	K0	K1	K2	K3	LSD p<0.05
specific leaf weight (g m^{-2})	28,1 (b)	25,1 (a)	25,6 (a)	24,8 (a)	*
hexose content of shoot apex (mg g^{-1})	3,3	4,7	12,0	17,9	NA
turgor pressure of leaves (Mpa)	-1,65	-1,34	-1,10	-1,46	NS

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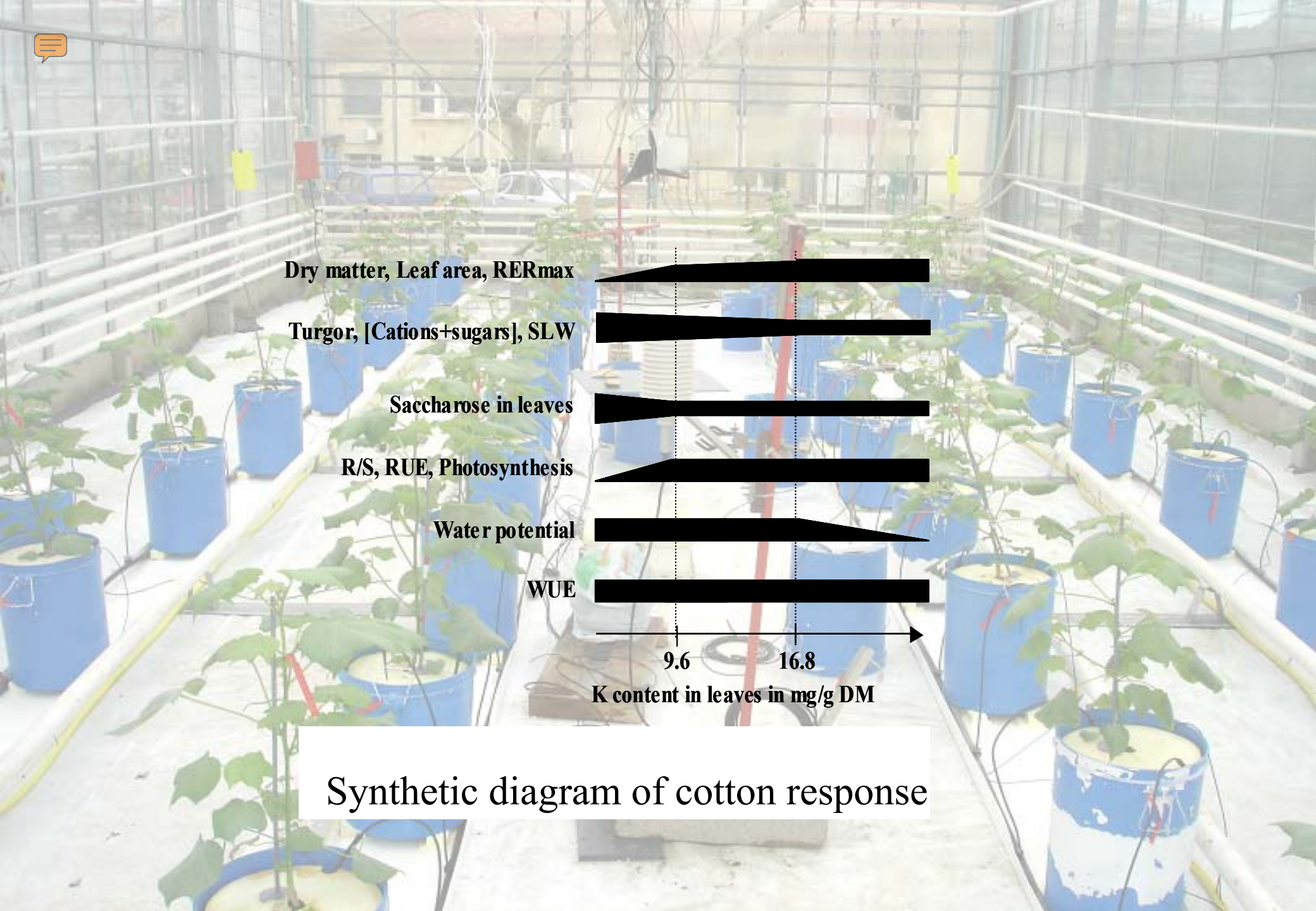
According to the various responses of the plants, we determine two threshold values : 1) 16.8 mg K /g DM below which the first signs of deficiency appear at the plant scale, and 2) below 9.6 mg K / g DM for drastic decrease in growth parameters.



Synthetic diagram of cotton response

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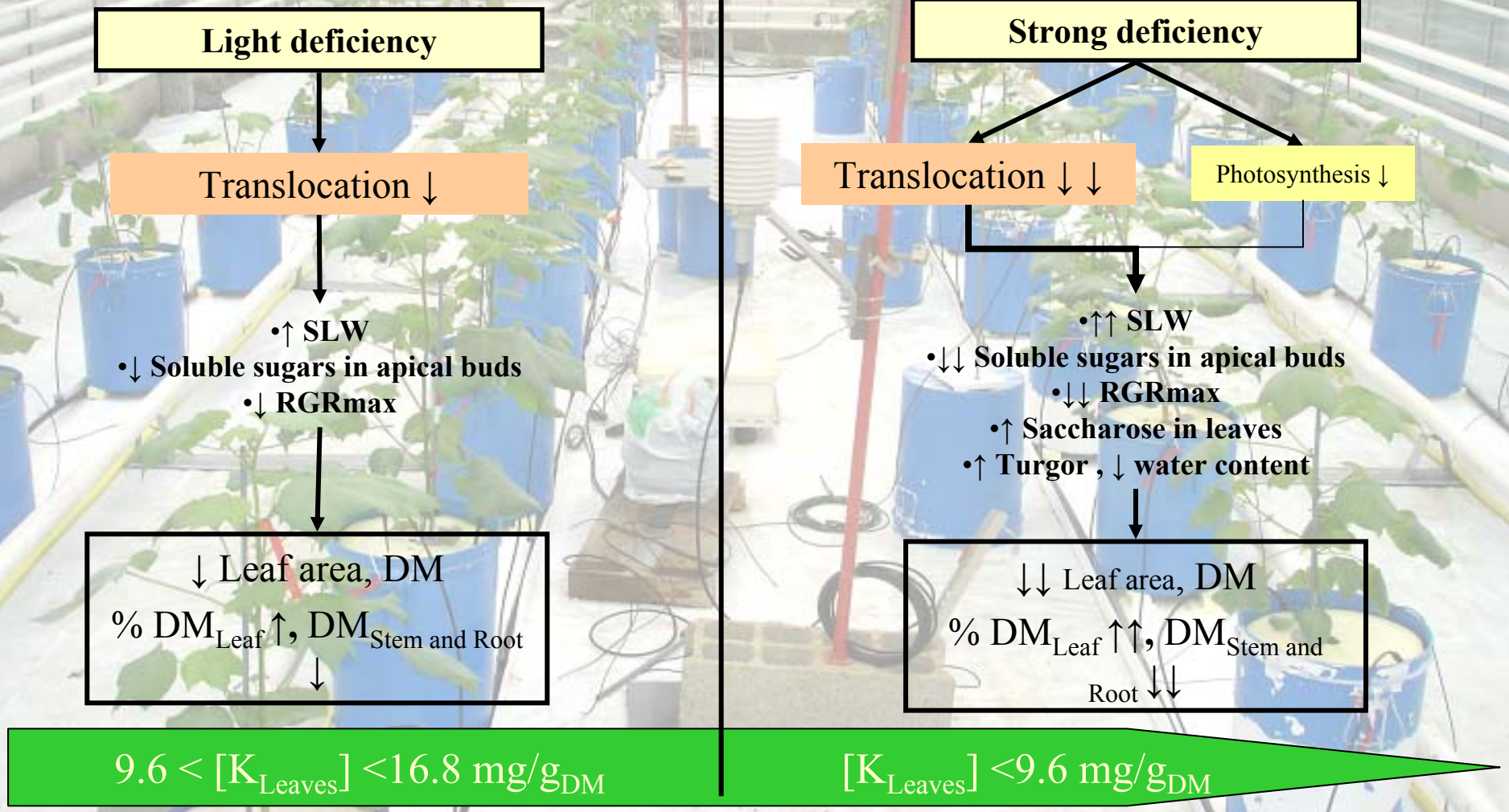
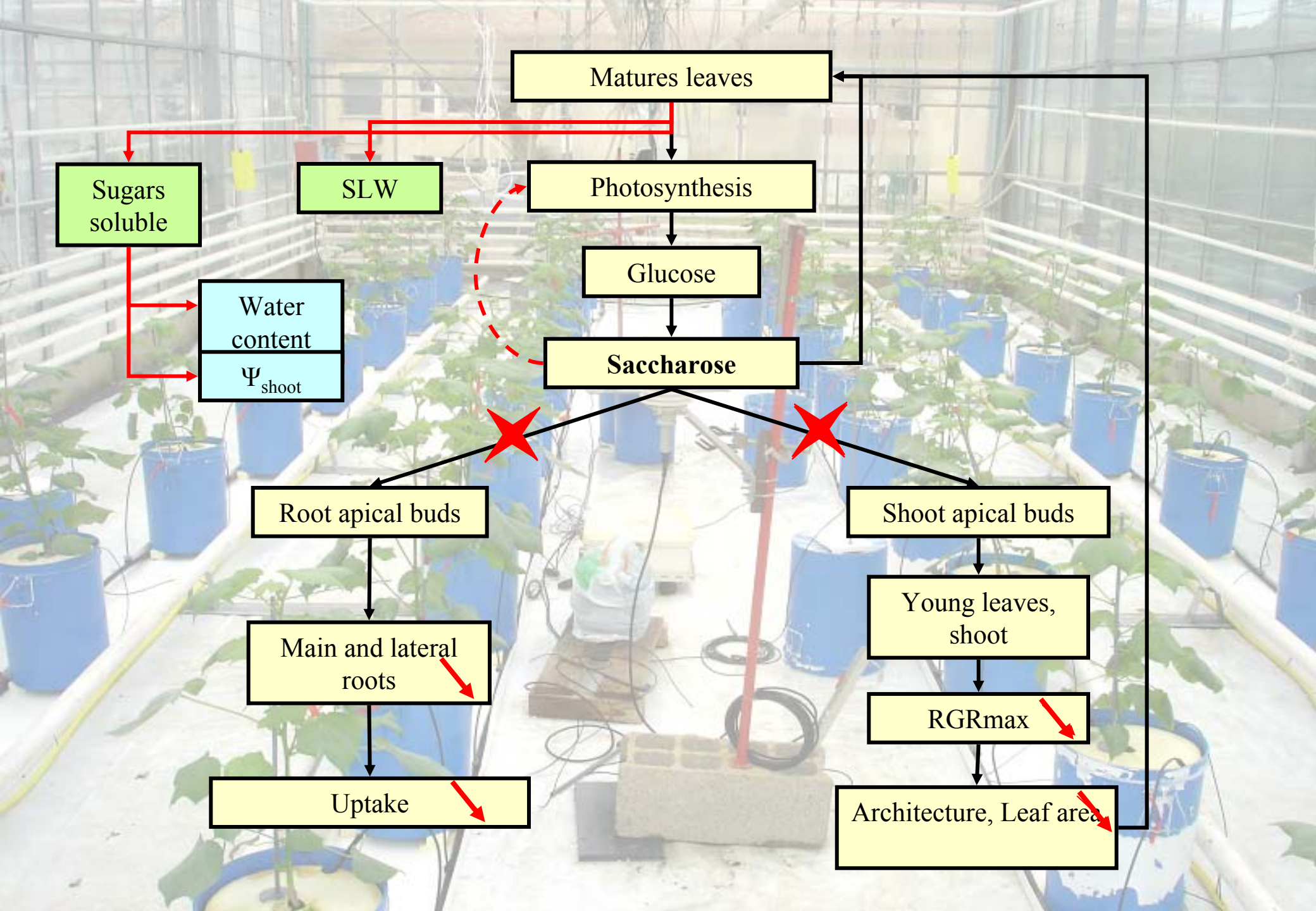
Finally, whatever the K defiency, the principal mechanism being disrupted seems to be translocation of saccharose in phloem. Modifications of other variables have minor effects (due to reduction of photosynthesis) or are the consequence of the accumulation of soluble sugars blocked in the leaves (water characteristics, distribution of biomass and RGR reduction).

Major problem of sugar transport




Matures leaves
Sugars soluble
SLW
Photosynthesis
Glucose
Water content
Ψ_{shoot}
Saccharose
Root apical buds
Shoot apical buds
Main and lateral roots
Young leaves, shoot
RGRmax
Uptake
Architecture, Leaf area


Thank you for attention and effort to understand